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Considerations Related to Richardson's Ground Squirrel (*Spermophilus richardsonii*) Control in Montana

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ABSTRACT

Alfalfa (*Medicago sativa* L.) production is limited in Montana due to activities associated with Richardson's ground squirrels (*Spermophilus richardsonii*), and control is often considered to be cost prohibitive. This study was conducted to document the economic impact of ground squirrel activities on alfalfa yield and demonstrate field efficacy of available toxicants. Montana alfalfa producers completed a survey to determine perceived severity and losses due to ground squirrels. Actual first-harvest forage yield losses were determined at two locations in southwest Montana in 2003 and 2004 using cage exclosures. Chlorophacinone (Rozol), diphacinone (Ramik-Green), and zinc phosphide were administered at two locations to determine the efficacy of each treatment. Survey results across Montana indicate alfalfa producers estimate a 24% average reduction in forage yield in areas known to be infested with ground squirrels. First-cut forage yields were reduced by 31% in southwest Montana. Rozol was the most effective control agent (84% efficacy) while Ramik-Green was the least effective control agent in our trials (29% efficacy). Landowner perceptions of ground squirrel damage are similar to actual yield reduction and possibly underestimated. The costs associated with the control of ground squirrels can be quite high, and caution must be exercised when implementing a new control program to assure these costs are offset by forage gained.

Maximum alfalfa production has been limited in Montana by activities of Richardson's ground squirrels. Ground squirrels invade alfalfa fields, establishing elaborate burrow systems, resulting in forage loss caused by both burrowing and feeding (Yensen and Sherman 2003). Montana State University (MSU) County Extension Agents have indicated that crop damage from ground squirrels has a major economic impact on agriculture producers in Montana. A single pair of ground squirrels and their offspring can remove 0.1 ha of alfalfa in one growing season (Lewis and O'Brien, 1990). In northeastern California, alfalfa yield loss estimates ranged from 35 to 46% due to Belding's ground squirrel (*S. beldingi*) activities (Whisson et al., 1999). In addition to this yield reduction, the mounds interfere with alfalfa harvesting (Whisson et al., 1999). Ground squirrel mounds can damage swathing equipment such as sickles and guards and create rough fields that are more difficult to harvest (Rulofson et al., 1993). Although many forms of control exist, agricultural producers are often hesitant to use them, as costs may be prohibitive and timing for best control interferes with other farm activities (Montana Dep. of Agric., 1996).

Ground squirrels consume a diet of grasses and forbs similar to that of cattle (Andelt and Hopper 1998; Askham 1994). The amount of alfalfa removed by ground squirrels is questionable. Due to favorable soil conditions and a nutritious food source, perennial alfalfa fields provide ideal habitat for ground squirrels. Ground squirrel population densities in these areas can exceed 330 ha^{-1}, and reduced yields result from the feeding and burrowing of ground squirrels.

Various control techniques are available to reduce ground squirrel numbers. Cultural control methods such as tillage, crop rotation, and flooding (Rulofson et al., 1993) are widely practiced in the USA to reduce populations of ground squirrels. Light spring disc harrowing is widely practiced in northern areas to level mounds created by ground squirrels and/or their predators. This practice has limited effects on ground squirrels but is detrimental to alfalfa stand longevity if practiced over multiple years (Welty et al., 1988). In severe infestations, growers are forced to rotate to other crops for one or more years before re-establishing alfalfa, which is costly and time-consuming. Biological control consists primarily of allowing/attracting natural predators. Shooting, trapping, bait stations, burrow fumigants, and grain baits are also often employed (Montana Dep. of Agric., 1996). Toxicants are often the most effective and economical method to control large populations of ground squirrels (Rulofson et al., 1993). Poison grain treated with zinc phosphide has shown an 85% reduction in ground squirrel populations when administered properly (Matschke et al., 1983). Further, this method of control has shown almost no impact on nontarget passerines (Apa et al., 1991). Anticoagulant baits such as chlorophacinone and diphacinone are effective when a continual supply of bait is consumed (Askham, 1994).

Crop yield reduction due to the activities of ground squirrels can be quite detrimental to a farming operation. Actual yield losses are likely overestimated at times (Yensen and Sherman, 2003). This overestimation can lead a producer to justify spending large amounts of money on control methods, sometimes unnecessarily. No accurate estimates of alfalfa yield reduction associated with ground squirrels are available to aid Montana alfalfa producers when considering ground squirrel management.

The objectives of this study were to document the economic impact of alfalfa losses due to ground squirrels (both perceived and real) and demonstrate field efficacy of available toxicants including zinc phosphide, diphacinone, and chlorophacinone.

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Abbreviations: MSU, Montana State University.

MATERIALS AND METHODS

Landowner-Perceived Losses Due to Ground Squirrels

A survey was mailed to 496 alfalfa producers throughout the state of Montana in March 2003 to determine perceived alfalfa losses due to ground squirrels. Names and addresses of potential survey participants were obtained from a sample of known alfalfa producers in each county, identified by MSU Extension Service County Agents. County agents provided names and addresses of 5, 10, or 20 alfalfa producers based on the size of the county and acreage in alfalfa. Respondents were asked to identify county of residence, the amount of deeded land seeded in alfalfa, average yield, percentage occupancy by ground squirrels, and yield reduction in occupied areas (see Fig. 1). Ground squirrels are not known to occupy southeast Montana, so that area was not included in the survey mailings. A nonresponse follow-up was not conducted. The Montana Agriculture Statistics Service administrative districts were used, and the results were tabulated in November 2003. Each survey parameter was analyzed by district, with each survey respondent considered an experimental unit in a completely random design. A single-factor analysis of variance (ANOVA) was used to test for significant differences among districts. Differences in regional means were considered significant at $\alpha = 0.05$. Means separation was obtained by calculating the 95% confidence interval for each mean and testing for overlap with Microsoft Excel.

Field Evaluation of Alfalfa Losses

Vegetative loss at first cutting due to activities associated with Richardson's ground squirrels was determined at two locations in Gallatin County, MT. These sites (Central Park and Belgrade) were selected based on previous known ground squirrel activity. The soil at the Central Park location is a Saypo silt loam, and the soil at the Belgrade location ranges from Attewan clay loam to Beaverell loam and a Beaverell-Beauvwan complex (USDA-NRCS, 2003). All soils are very deep (more than 152 cm) alluvium and range from well to moderately well drained (USDA-NRCS, 2003). The major land use is hay, pasture, and grain production at both sites. Mean precipitation at those locations of the county is 36 cm yr^{-1}, about 70% of which falls during the April–September growing season. The mean annual temperature is 5.6°C (USDA-NRCS, 2003).

Ground squirrel monitoring and treatment experiments were conducted near Central Park in 2003 and 2004 and at Belgrade in 2004. In 2003, three exclosure cages were erected near Central Park, before spring green up, in areas of varying ground squirrel occupancy, based on visual observation. Exclosures were 91 by 91 cm, 61 cm tall, and constructed of 2.54- by 1.27-cm wire mesh. Exclosures were secured at corners by 0.64-cm steel stakes, and the lower edges of the cages were secured to the ground (Whisson et al., 1999). Alfalfa first-cut yields were determined by clipping a total of six 0.25-m^2 quadrats, three located within the exclosures and three in unprotected adjacent areas of similar ground squirrel density. The unprotected plots were randomly selected by tossing a quadrat frame within 10 to 15 m from the exclosure. This procedure was followed at both locations in 2004, using four exclosures per site.

Alfalfa collection was limited to the first cutting to minimize crop disturbance. Alfalfa samples were dried for 48 h at 60°C and weighed at the MSU Animal Nutrition Center in late June 2003 and 2004. Forage plots at each location were averaged for a total of three paired comparisons. Comparisons between

MSU Ground Squirrel Survey for Alfalfa Producers

1. How many acres of alfalfa hay or alfalfa-grass hay did you have last year? _____ acres
2. What were the average tons per acre you produced? _____ tons per acre
3. What percentage of your alfalfa hay or alfalfa-grass hay acreage was impacted by ground squirrels? _____ % of my alfalfa land was impacted by ground squirrels.
4. On those acres impacted, what percentage do you think ground squirrels reduced alfalfa hay or alfalfa-grass hay production? Where ground squirrels occurred, my production was reduced by _____ %.
5. I live in ___________ County.

Thank you for your help.

Postage has been prepaid. Simply drop in mailbox after filling out this postcard.

Fig. 1. Postcard survey mailed to 496 alfalfa producers throughout Montana in March 2003.

protected and unprotected alfalfa were evaluated with a paired *t* test. Differences were considered significant at $\alpha = 0.05$.

Alfalfa forage values for first harvest were assumed to be the current (2003) value of hay or pasture, or \$76.65 Mg^{-1}. First-harvest yields under irrigation in southwest Montana are typically 45 to 55% of total annual production in a three-cut system (Cash et al., 2005). This was used to compare the economic feasibility of chemical control methods.

Comparison of Control Methods

Three chemical control treatments were evaluated in 2003 and 2004. In 2003, the center of an alfalfa field near Central Park was subdivided into four 0.4-ha plots. In 2004, this procedure was repeated at that location and at an additional site near Belgrade, MT. One of the following treatments was randomly assigned to each plot: single lethal dose of zinc phosphide treated oat (*Avena sativa* L.), diphacinone anticoagulant bait stations (containing Ramik-Green), chlorophacinone anticoagulant bait (Rozol), and a control. Plots receiving the zinc phosphide treatment were prebaited with untreated oat to establish bait acceptance before poisoning. The initial chlorophacinone (Rozol) and prebait applications for zinc phosphide treatments were administered on 31 Mar. 2003 and 30 Mar. 2004. Bait stations containing Ramik-Green were erected 8 d before these initial applications each year because a 1- to 2-wk familiarization period is needed before ground squirrels will accept bait from stations (Montana Dep. of Agric., 1991). The zinc phosphide and second Rozol application was administered on 2 Apr. 2003 and 1 Apr. 2004. Procedures followed label directions and recommendations described by the Montana Department of Agriculture (1996). Plots designated as "control" were not disturbed. Each plot represents one experimental unit, resulting in only one replicate at each location, each year.

Before treatment applications, ground squirrels were collected and sex determinations made until the sex ratio of squirrels taken in each plot approached 1 male:1 female because male ground squirrels emerge approximately 2 wk before females (Andelt and Hopper, 1998). Ground squirrels outside of the test area were removed with a .22 caliber rifle to minimize disturbance.

Ocular estimates of ground squirrel numbers and activity were obtained by surveying the area once a day for 8 d before the treatments. An observer stood at a central location between the four plots and, after a 10-min acclimation period, visually counted ground squirrels appearing in 5-min intervals in each 0.4-ha plot. Each plot was surveyed, beginning with a

Table 1. Hectares in alfalfa production, average yield, percentage occupancy by ground squirrels, and yield reduction from a survey of Montana's alfalfa producers.

District	Alfalfa or alfalfa/grass production			Estimated percentage occupied by ground squirrels	Estimated percentage loss in hay production
	no.	ha	Mg ha^{-1}	%	%
Northwest	36	86.2 ± 5.3[a]†	8.50 ± 0.56[b]	14.9 ± 4.3[a]	18.9 ± 2.7[a]
North central	42	115.7 ± 6.9[b]	5.00 ± 0.52[a]	37.9 ± 6.1[c]	23.2 ± 3.9[a,b]
Northeast	11	93.9 ± 4.9[a]	4.98 ± 0.94[a]	28.8 ± 10.5[a,b,c]	37.8 ± 7.1[c]
Central	87	225.0 ± 8.1[d]	4.39 ± 0.45[a]	28.4 ± 4.1[c]	26.3 ± 2.5[b]
Southwest	46	194.3 ± 9.7[c]	8.34 ± 0.34[b]	29.0 ± 4.8[b,c]	22.0 ± 2.7[a,b]
South central	52	125.5 ± 7.3[b]	5.34 ± 0.54[a]	19.7 ± 4.5[a,b]	25.7 ± 4.4[a,b]
All	274	152.2 ± 9.7	5.94 ± 0.22	26.7 ± 2.0	24.4 ± 1.4

† Different superscripts indicate significant differences ($P < 0.05$) between regions.

different plot each day, and continuing in a clockwise direction, every 5 min. While survey time varied slightly, surveys were usually completed midmorning. These observations were averaged to obtain a population estimate in each plot before treatment application. For 7-d post-treatment, similar observation counts were made. These observations were averaged to obtain a post-treatment population estimate at each plot.

Chemical treatment data collected were analyzed using analysis of variance (ANOVA). Means for ground squirrel population estimates and percentage control were each separated by Fisher's LSD generated from a mean square of the error term from the corresponding ANOVA. Paired t tests were used to compare population estimates before and after each treatment was administered. Differences were considered significant at $\alpha = 0.05$.

RESULTS

Landowner-Perceived Losses Due to Ground Squirrels

Two hundred eighty-eight (288) surveys were returned (response rate of 58%). Of these, 274 contained usable information. The remainder of surveys returned were either incomplete, blank, or otherwise unusable. The 274 responses represented 42 000 ha, or 8% of Montana alfalfa acreage (Stringer and Lund, 2003). Survey responses indicate perceived vegetative loss from ground squirrels is highest in the northeast part of the state (Table 1) although this may be biased due to low sample size.

Respondents estimated that, on average, 27% of hayland is occupied by ground squirrels and perceive there is a 24% reduction of alfalfa production in those areas. Based on a statewide total alfalfa loss of 6.4%, this represents an average annual loss of 10 ha of alfalfa, or 58 Mg of alfalfa, or \$4400 (at \$76 Mg^{-1}) per producer in Montana. According to these estimates, losses may be as great as \$7 million dollars annually in Montana.

Responses varied considerably by region (Table 2). Reasons for these differences are unclear but may be a result of difference between stand age, composition (alfalfa vs. alfalfa/grass), whether dryland or irrigated, soils or yield at each cut, factors which our survey was not designed to distinguish.

Table 2. Regional alfalfa loss from a survey of alfalfa producers' perceptions about alfalfa and ground squirrels in Montana. Total loss equals estimated percentage occupied by ground squirrels multiplied by percentage perceived loss in occupied areas.

District	n	Mean	SE
Northwest	36	2.42[a]†	0.76
North central	42	8.15[c]	2.15
Northeast	11	13.18[c]	7.02
Central	87	7.33[c]	1.32
Southwest	46	5.04[b]	0.73
South central	52	7.74[b,c]	2.81
All	274	6.4	0.01

† Different superscripts indicate significant differences ($P < 0.05$) between regions.

Field Evaluation of Alfalfa Losses

Although exclosures were placed in areas of varying infestation levels, data were combined to obtain overall averages within and outside of exclosures due to low sample sizes. Even so, evidence clearly suggests that ground squirrels have significant impacts on overall alfalfa yield. Field evaluation indicated that alfalfa yield was reduced from 4025 kg ha^{-1} in protected areas to 2793 kg ha^{-1} in nonprotected areas ($P = 0.045$; $n = 3$). This is representative of an overall alfalfa yield reduction of 31% in areas occupied by ground squirrels. Individual yield loss across 10 exclosures ranged from none to 60%.

Comparison of Control Methods

Chemical control methods varied from 29% efficacy for Ramik-Green to 84% efficacy for Rozol (Table 3). Based on these trials, Rozol and zinc phosphide are both effective ground squirrel control agents ($P = 0.039$ and 0.011, respectively). Ramik-Green was not effective at reducing ground squirrel numbers ($P = 0.281$) based on our methods. We observed a reduction in ground squirrel numbers at all sites after treatment application although the reduction at the control site was not significant. Although effectiveness varied slightly from site to site, Rozol was the most effective treatment across all

Table 3. Average number of Richardson's ground squirrels observed in 0.4-ha plots at two locations in 2003 and 2004 during repeated 5-min surveys at each treatment before and after application of three chemical treatments ($n = 3$).

	Before	After	Reduction	SE	P
	no.	no.	%		
Rozol	16.7[a]†	2.7[b]	84	2.51	0.039
Ramik-Green	11.4[a]	8.0[a,b]	29	2.84	0.281
Zinc phosphide	13.4[a]	5.6[b]	58	1.58	0.011
Control	14.3[a]	13.1[a]	9	2.33	0.489

† Values within a column with different superscripts are significantly different ($P < 0.05$) by Fisher's protected LSD.

sites and years. Zinc phosphide was somewhat effective at our sites under Montana conditions at 58% reduction in ground squirrel numbers.

DISCUSSION

Landowner-Perceived Losses and Actual Yield Reduction

According to the survey, respondents in southwest Montana perceive a 22% alfalfa yield reduction in areas occupied by ground squirrels. Our measurements in southwest Montana documented that actual losses in that area are about 31% for first-cut alfalfa. This indicates that landowner perceptions are similar to and may possibly underestimate actual yield reduction. Results may be slightly skewed because our measurements were for first-cut only, and producers were asked to estimate annual yield loss.

If perceptions are similarly accurate throughout Montana, alfalfa losses due to ground squirrels may be higher than had previously been assumed. It would be advantageous to erect numerous ground squirrel exclosures at various known ground squirrel infestations throughout the state.

National surveys (Conover and Decker, 1991; Wywialowski, 1994) cited damage to crops as the most significant negative impact of wild ungulates on agricultural operations. In southwestern Montana, the cost of forage consumption by big game (deer and elk) averaged $5616 per landowner (Lacey et al., 1993). According to our findings, alfalfa consumption and associated activities of ground squirrels likely impact Montana's economy on a scale similar to that associated with large ungulates. Because ground squirrels are not as visible as large ungulates (especially once vegetation matures) the economic impacts of ground squirrels in Montana are not often considered.

The yield reduction data was collected from the first cutting of alfalfa only. Subsequent clipping would have been more informative; however, we were precluded from clipping second or third alfalfa cuttings due to landowner concerns. Comparisons would have to be made at each harvest stage to accurately assess overall economic effects on alfalfa yield reduction. Even this would not present a complete picture of economic effects due to ground squirrels. The costs associated with damaged farming equipment, or modification of farming practices due to ground squirrel occupancy, have not been documented and are greatly needed.

Comparison of Control Methods

Zinc phosphide achieved an efficacy rate at one site of 72% in 2003. Unfortunately, we received a precipitation event (both rain and snow) within 24 h of our zinc phosphide treatment, during each year at both locations. Because zinc phosphide converts to phosphene gas when moist, the bait is ineffective after it becomes wet. Under ideal conditions, zinc phosphide can be 85 to 90% effective (Askham, 1994) but was 58% effective in this trial. Zinc phosphide is most attractive due to its low price, about $2.20 kg^{-1}.

Table 4. Comparison of registered toxicants to control ground squirrels at two locations in southwest Montana, 2003 and 2004. Cost per hectare indicates monetary costs associated with chemical purchase, and man-hours per hectare indicates time required for chemical application.

	Application rate		Cost per hectare		Man-hours per hectare	
	Moderate	Heavy	Moderate	Heavy	Moderate	Heavy
	kg ha^{-1}		\$ ha^{-1}		h ha^{-1}	
Zinc Phosphide	1.49	2.81	$3.75	$7.21	0.13	0.25
Rozol	2.81	6.17	$13.59	$29.90	0.11	0.25
Ramik-Green	11.22	22.45	$43.24	$86.49	0.06	0.12

Rozol was consistently the most effective toxicant at all locations in our control trials. At moderate infestation levels, it cost $13.59 per hectare to apply and up to $29.90 per hectare to apply at highest infestations (Table 4). The cost figures for moderate-infestation areas are representative of locations that required the least amount of toxicant to treat. Likewise, the high-infestation figures are from highly infested locations that required the greatest amount of toxicant to achieve satisfactory coverage. Although moderately expensive, Rozol is recommended for early-spring use when precipitation is unpredictable.

Although Ramik-Green showed poor results in our trials, it should not be disregarded as a means for ground squirrel control. Diphacinone is an anticoagulant designed to achieve gradual control. Ground squirrels generally require a 1- to 2-wk familiarization period to become accustomed to feeding from bait stations. After regular ingestion of the bait begins, an average of 5 to 10 d is needed before a lethal dose is ingested (Montana Dep. of Agric., 1991). Due to this slow mode of action, the authors were faced with a decision to either use a different monitoring strategy for Ramik-Green treated areas or include the Ramik-Green treated plots with the ocular counts for the other treatments and control, with the possibility of results being slightly skewed. It was chosen to monitor all plots identically to maintain consistency of measurements across treatments. Bait stations containing Ramik-Green remained in alfalfa fields until all bait was consumed, and we believe ground squirrel mortality continued throughout this duration. One author found ground squirrel carcasses with evidence of internal hemorrhaging adjacent to bait stations weeks after observational counts ceased. Furthermore, because bait stations were placed in the alfalfa field before the initial counts, it is possible the initial ground squirrel population estimates may have been artificially lowered due to premature control. Ramik-Green was also very costly to apply (Table 4); however, bait stations are self-maintaining once erected, which is an advantage compared with the other toxicants that are administered by hand, one burrow at a time.

These results must be interpreted cautiously. Alfalfa damage and control data at two Montana locations are likely representative of this area; however, the overall sample sizes were quite low. It would be advantageous to repeat these control trials for multiple years at various locations throughout the state to confirm our results.

Cost-Effectiveness of Control

At our research locations in southwest Montana, ground squirrels removed 31% of first-cut alfalfa in heavily infested areas. At current yields, this equates to about 1199 kg ha^{-1}, or $91 of alfalfa per hectare per year. Product efficacy ranged from 29 to 84%. Administering a control treatment does not ensure complete control or maximum forage yield during the year of treatment. Further, the cost per hectare to treat ground squirrel infestations does not take into account time and labor costs, which can greatly influence the decision to control rodent populations. Estimates of monetary cost and labor required to treat ground squirrels at moderate and heavy infestations are included in Table 4. Labor wages can vary considerably. A number of factors should be taken into consideration before implementing a ground squirrel control program. These include level of infestation, amount of forage lost, age of the alfalfa stand, efficacy of control agent, and treatment and labor costs involved with timely control of this pest. Finally, any rate of return to pre-ground squirrel conditions is unknown and may vary in accordance with ground squirrel density and length of occupation.

CONCLUSIONS

The economic impact of ground squirrels in Montana is substantial and probably greater than was previously thought. Landowners' perceptions of ground squirrel damage are similar to actual yield reduction and possibly underestimated. In field evaluations in southwest Montana, ground squirrels actually removed 31% of available alfalfa compared with an average perceived loss of 22%. If landowner perceptions are as accurate throughout the rest of Montana, ground squirrels damage exceeds $7 million annually.

Zinc phosphide proved to be the least expensive control method tested while Rozol was the most effective for Montana conditions, with an average efficacy of 84%. Ramik-Green was the most expensive control agent to administer and is suggested for use only in small areas or low infestations. The relative high cost of Ramik-Green makes it impractical for large applications.

While previous authors suggest economic losses due to ground squirrels are often overestimated (Yensen and Sherman, 2003), and we believe this may be the case at times, our findings suggest alfalfa producers may actually underestimate crop reduction due to activities associated with ground squirrels. If losses are overestimated, alfalfa producers may unnecessarily invest large amounts of money with little return. In fact, the opposite may be true. It is obvious at the two locations in southwest Montana where yield reduction was documented and control efforts implemented that the value of the additionally harvested alfalfa far exceeded the costs associated with control. Great care must be taken when determining appropriate ground squirrel management strategies. Ground squirrel control can be costly, and producers should consider costs of short- and long-term control practices.

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